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Flight behavior of *Luehdorfia japonica* (Lepidoptera, Papilionidae) at the summit area of Mt Egesan, Hiroshima City

2. Peak-to-peak translocation of males in 2003, 2004 and 2005

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Abstract In 2003, we marked 44 individuals of *Luehdorfia japonica* at the five peaks (Peaks A–Peak E) of Mt Egesan, and tried to recapture them at the peaks. We detected 25 occurrences of peak-to-peak translocations by 13 individuals, and 15 translocations among the 25 were manifested on the same day. Direct peak-to-peak distances were, Peak A–Peak E, 460 m; Peak D–Peak E, 420 m; Peak A–Peak D, 340 m; and Peak A–Peak B, 125 m. In 2004, we marked 27 individuals, and eleven translocations on 5 individuals were detected. Eight translocations among the eleven occurrences were detected on the same day. In 2005, we marked 52 individuals, and 17 translocations on nine individuals were detected. Five translocations among the 17 occurrences were detected on the same day. As is also explained in another manuscript (Watanabe and Hirano, 2006), the male flight behaviors of *Luehdorfia japonica* at the summit area are categorized into at least three types; round-patrolling with rests at specific points, perching occupation with repeated circular flights, and peak-to-peak translocation. Implications of the flight behaviors are discussed in regards to the mating activities of males coupled with the avoidance of population divergence.

Key words Marking, flight, peak, hill topping, translocation, *Luehdorfia japonica*, mating behavior, population divergence, population convergence.

Introduction

During the course of male flight analysis using the mark-recapture method, on April 19, 2002 we succeeded in proving a peak-to-peak flight and, surprisingly, the individual returned back (home-in) to the original peak. This was at least greater than 680 m of flight within four hours (Watanabe and Hirano, 2006). The fact clearly indicates that the butterflies display such long-distance round trips from peak to peak. To grasp the extent of the flight activity, we tried to make more intensive studies by mark-recapturing in 2003, 2004, and 2005.

Materials and methods

1. The survey point, Mt Egesan (Figs 1, 2)

Mt Egesan is a municipal mountain park of Hiroshima City, which is located in the eastern area of Hiroshima Bay (Fig. 1). Characterization of the locality as a habitat of *Luehdorfia japonica* was described in another manuscript (Watanabe and Hirano, 2006). As the circumstances of area have drastically changed recently due to the construction of a microwave tower for digital TV, we are now trying to reconstruct, with the municipal officers,

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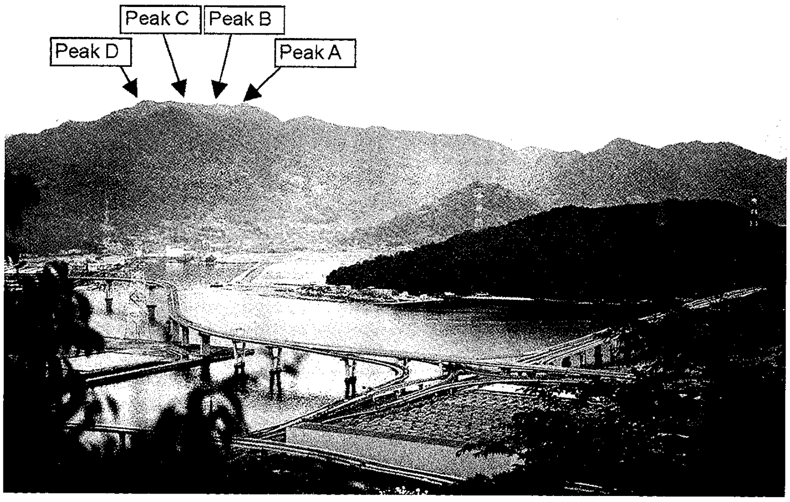

Fig. 1. Mt Egesan, viewed from Mt Ogonzan (alt. 210 m), 7.4 km northwest from the summit of Mt Egesan. Peak E is behind Peak B.

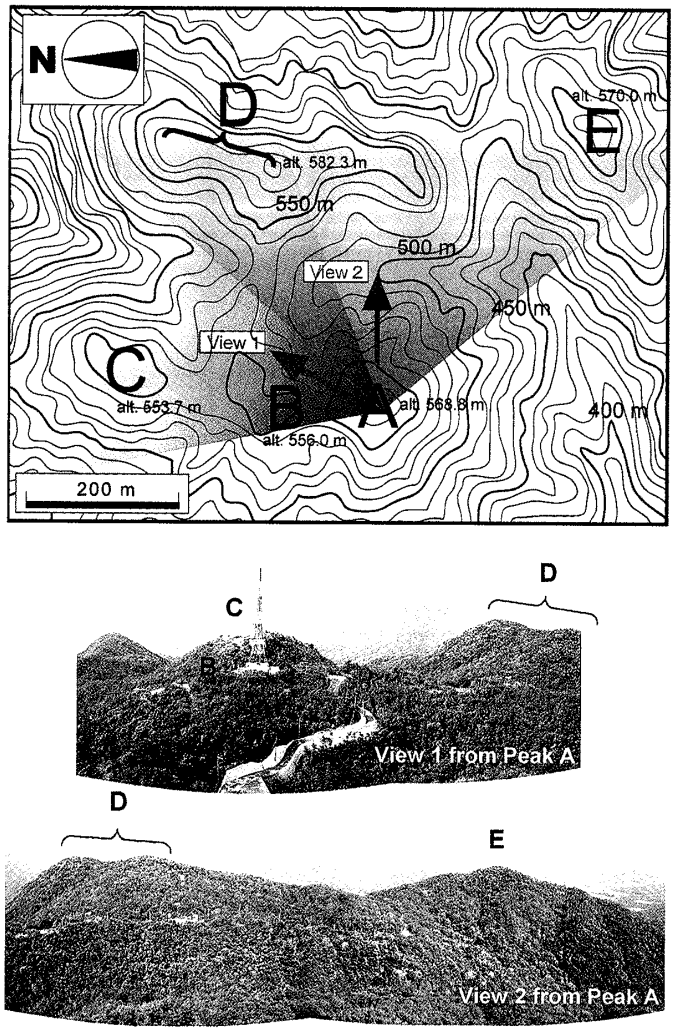

Fig. 2. Summit area (Peaks A, B, C, D and E) of Mt Egesan. Photographs are the Peaks, viewed from the height of 68 m above the top of Peak A, where a microwave tower for digital TV (height of 121.03 m) is now under construction.

a good *Luehdorfia* habitat based on our investigations. So, the collection of butterflies and/or eggs and food plant in the area should be avoided.

2. Marking of individuals and following-up of their flight activities

The marking method was also given in the other paper (Watanabe and Hirano, 2006). In brief, the marking was made on the ventral surface of the hind wing using color magic pens (oil-type, Mackie-Gokuboso, Zebra Co.). All the individuals captured at the summit area, Peak A–Peak E (Fig. 2), were marked and released. After that, all the individuals which we could find were captured once, and their markings, time, and place of recapturing, and the degree of staining were recorded. If the individual had no marking, we made a marking, recorded, and released it.

The days of the survey by the three members are shown individually in Figs 3, 5, and 7. We mainly moved among Peak A, Peak D, and Peak E, because we knew that the chances of recapturing were generally high at these peaks. In other words, we were generally trying to get the highest recapturing rates. When there was a day in which more than one member were on survey, we did our best to move away from each other and to be scattered widely. Peak B was located on the route to Peak A, so we always visited Peak B for a short time when moving from Peak A (or to Peak A). Visits to Peak C were restricted because there were, generally, few butterflies. It takes about 20 minutes to walk from Peak A to Peak D, 30 minutes from Peak A to Peak E, and 25 minutes from Peak D to Peak E.

As we could not cover all the peaks all the time in the survey day, we have avoided statistical discussions.

Results

1. Peak-to-peak translocations in 2003

Mark-recapturing at the five peaks in 2003 is summarized in Fig. 3, and the details of peak-to-peak translocation, as far as detected, are summarized in Fig. 4. Even though we surveyed the appearance of butterflies from April 1, the first appearance at the peaks was on April 15 in that year. As the first appearance in a usual year was around April 5 (Watanabe, 1998), the year 2003 featured an unusually late-arrival of *Luehdorfia* at the peaks. We marked 44 individuals (43 males and one female).

The first long-distance translocation on the same day was proven on April 17 for individual No. 11, which was marked at 11: 35 at Peak D, and was recaptured at 12: 00 at Peak A, 340 m west from Peak D. It took 25 minutes, which was the fastest case (Table 1). The term "translocation" is used when "an individual first captured (marked) at a certain peak (Peak A–Peak E) was recaptured or confirmed at a different peak". This individual (No. 11) was stained at the time of the first capturing and marking.

After that, we could detect 25 translocations on 13 individuals (faint mesh in Fig. 3), and 15 translocations (dark mesh in Fig. 3) among the 25 occurrences were detected on the same day (Figs 3, 4).

2. Peak-to-peak translocations in 2004

The data obtained in 2004 are summarized in Figs 5, 6. As for *Luehdorfia*, 2004 was a year of early spring. We marked a very fresh individual on March 31 at Peak E. After that, we marked 26 male individuals and one female individual at the summit area (Fig. 5). In that year, the number of emerged individuals seemed to be small. Eleven translocations on five

No.	Marked by H, W, or K	2003																														
		31-Mar	1-Apr	2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr	11-Apr	12-Apr	13-Apr	14-Apr	15-Apr	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr	23-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr	29-Apr	30-Apr
		W			K	W	W,K	W,K	W,K			K			W,K		H,W,K	H,K	H,W	H,W			H,W	H,W,K	W			W	H,W,K	H	H,W	
1	K (1)																A							B								
2	H (1)																E	E														
3	H (3)																	C	C													
4	W (1)																	A														
5	W (2)																	A	A													
6	W (3)																	A														
7	W (4)																	A														
8	H (4)																		E													
9	H (5)																		E	E				E						E		
10	H (6)																		D													
11	H (7)																		A,D					A				E	E	E		
12	H (8)																		D					A,D,E				E	A,D,E	A,E	D,E	
13	H (9)																		A					D,E				E	E			
14	H (10)																		D	D				D								
15	W (5)																			E									A,E			
16	W (6)																			E												
17	W (7)																			E									E			
18	W (8)																			A,E												
19	H (11)																						E	B								
20	H (12)																						E									
21	H (13)																						B	A,B								
22	W (9)																						E									
23	H (14)																							E								
24	H (15)																							E								
25	H (16)																							E								
26	H (17)																							C					D,E	D	E	
27	H (18)																							A								
28	H (19)																							E					A			
29	H (20)																							E								
30	H (21)																							A,B								
31	W (10)																							A								
32	W (11)																							A								
33	W (12)																											E	E			
34	W (13)																											E	E			
35	K (2)																												A			
36	K (3)																												A			
37	H (22)																												E			
38	H (23)																												E	E		
39	H (24)																												E	E	E	
40	H (25)																												E			
41	H (26)																												E	A		
42	W (14)																												D,E			
43	W (15)																												E			
44(♀)	H (2)																	D														

Fig. 3. The marking and recapturing in 2003. H: Marked by Hirano, W: Marked by Watanabe, K: Marked by Kameyama,. A, B, C, D, and E; Peak A, Peak B, Peak C, Peak D, and Peak E. Faint mesh means individuals which made peak-to-peak translocation. Dark mesh means individuals which made peak-to-peak translocation in the same day. The expressions are used also in Fig. 5 and Fig. 7.

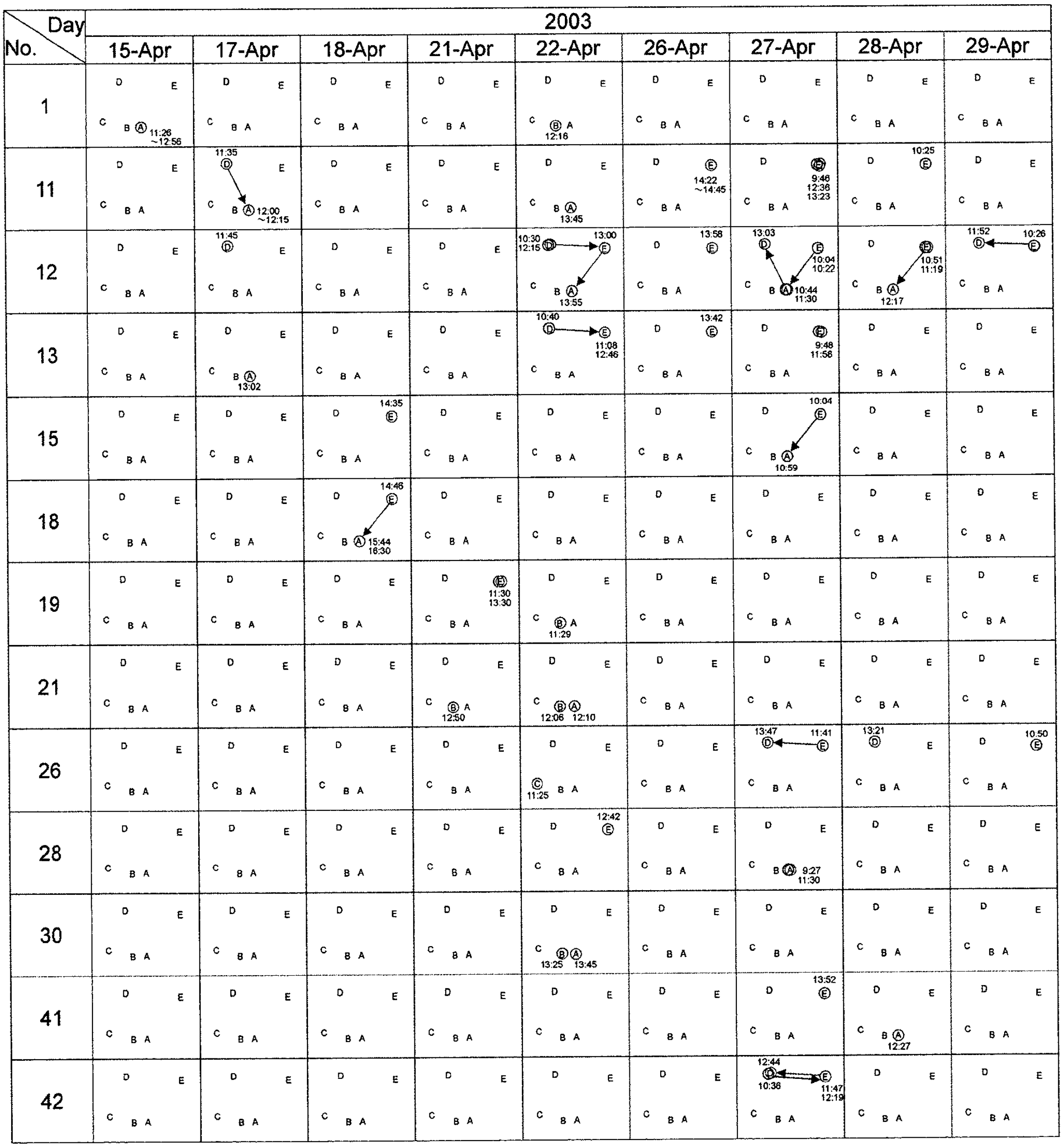

Fig. 4. The detailed peak-to-peak translocations in 2003, as far as was detected by our survey. A, B, C, D, and E in the figures mean Peak A, Peak B, Peak C, Peak D, and Peak E. The positions of A–E should be referred to Fig. 2. Blue circles mean 9: 00–10: 59, green circles mean 11: 00–12: 59, and red circles mean 13: 00–17: 00. Arrows indicate the direction of flight with assigned periods of translocation (same color as in the circles). Times shown in the figure (black) mean the times of confirmation of the individual at the peak. This does not always mean the final time or first time of confirmation at the peak. The expressions are used also in Fig. 6 and Fig. 8.

individuals were detected, and eight translocations among the eleven occurrences were detected on the same day (Figs 5, 6).

A translocation was first detected from April 12 to 13. The individuals detected translocating were always stained individuals, suggesting that translocations did not occur at earlier phases of adult emergence.

No.	Marked by H, W, or K	2004																														
		31-Mar	1-Apr	2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr	11-Apr	12-Apr	13-Apr	14-Apr	15-Apr	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr	23-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr	29-Apr	30-Apr
		H,W	H	H	H	H	H	H	H	H,W	H,W,K	H,K	H	H	H,W,K		H,W	W,K	H	H,K		H	H	H	H	H,W				W		
1	W (1)	E	E	E																												
2	H (1)									E	E	E		E																		
3	H (3)										C																					
4	K (1)										A																					
5	H (4)											A		A																		
6	H (5)											B																				
7	H (6)											E		E	E		E															
8	H (7)													E	A																	
9	H (8)													A				A·E														
10	K (2)														A		A			A												
11	K (3)														A		E	E														
12	K (4)														A·B		A	A	A	A·E		E	A·E	E								
13	H (9)														E																	
14	W (2)														E								E	E								
15	H (10)																E	A·B·D		D												
16	K (5)																	E		E		E										
17	H (11)																		E													
18	K (6)																			A												
19	K (7)																			E			E	E								
20	K (8)																			E												
21	K (9)																			E												
22	K (10)																			E												
23	H (12)																					E	E	E								
24	H (13)																					E	E	E	E							
25	H (14)																							A								
26	H (15)																							E								
27(♀)	H (2)									E																						

Fig. 5. The marking and recapturing in 2004.

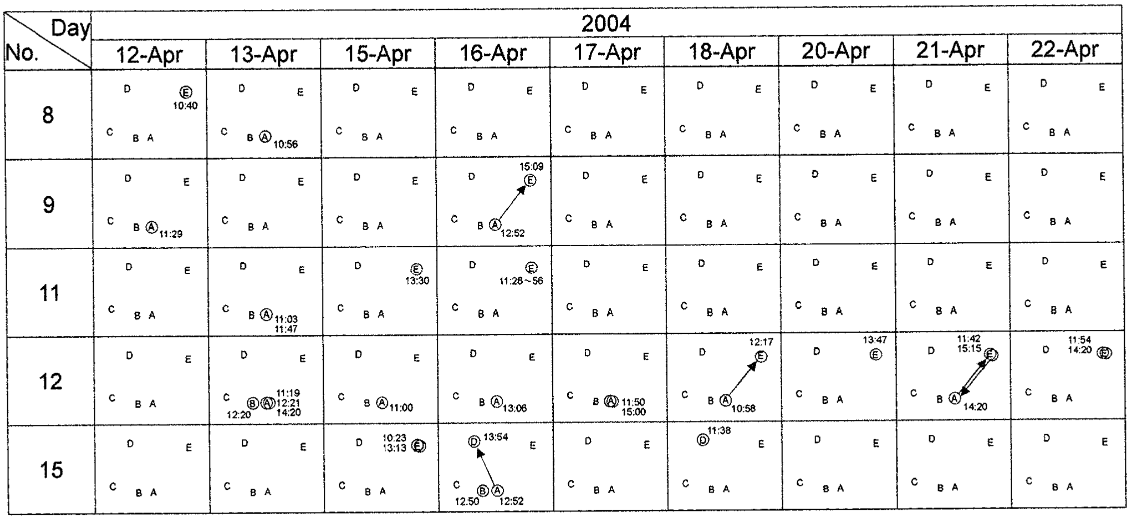

Fig. 6. The detailed peak-to-peak translocations in 2004, as far as was detected by our survey.

3. Peak-to-peak translocations in 2005

The data obtained in 2005 are summarized in Figs 7, 8.

This year saw an unusually late-arrival of *Luehdorfia* at the peaks. We started the survey from April 7, but we could not find any individuals until April 14. And, even by April 28, we found 12 non-marked male individuals. And, four individuals among them showed only some staining on their wings. Further, interestingly, we found multiple fresh female individuals at Peak E on April 16.

We marked 52 individuals (46 males and 6 females) (Fig. 7). And, 16 translocations on 9 individuals were detected, and five translocations among the 16 occurrences were detected on the same day (Figs 7, 8).

4. Time needed for translocation

The shortest time to make a peak-to-peak long trip was 25 min from Peak D to Peak A (340 m in shortest distance) by No. 11 on April 17, 2003 (Fig. 4, Table 1). If the recapturing at 12: 00 was just after the final release at 11: 35. We have to emphasize the duration is quite long because it takes only a few or several minutes to translocate by direct flight without stopping (5.7 minutes when flight speed was 1 m/sec). We do not mention any more than the described facts in Table 1, since we cannot know where and how the released individuals behave until the next recapturing.

5. Individual differences in translocating activities

We can point out the presence of active translocators (individuals No. 12 in 2003, No. 12 in 2004, and No. 4 and No. 5 in 2005) (Table 1). Although we do not know strictly how the remaining individuals behave, our impression is that they do not translocate, but are displaying round patrollings at restricted peak areas (Watanabe, 1998; Watanabe and Hirano, 2006).

6. Diurnal changes and age-dependence of translocation

Although we still do not have enough data, evidence of a first detection in a morning was at 10: 44 and the last one in an afternoon was at 15: 46, suggesting the translocations seem to start around 10 o’clock and continue all day long.

No.	Marked by H, W, or K	2005																														
		31-Mar	1-Apr	2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr	11-Apr	12-Apr	13-Apr	14-Apr	15-Apr	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr	23-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr	29-Apr	30-Apr
			K			K				W,K	W,K				K	W,K		W,K	W,K	K	K		W,K	W,K		W,K				W,K	W	W
1	K (1)										(Observed one fresh male without marking)					E																
2	K (3)															D																
3	W (1)																	E		E	E		E	E		E						
4	K (7)																		A,E	D	A		D									
5	K (8)																		D,E	D	D		D	E								
6	K (9)																		D													
7	K (10)																		A													
8	W (3)																		E					E							E	
9	W (4)																		E													
10	W (5)																		E													
11	W (6)																		B,E	B	D											
12	K (11)																			E												
13	K (12)																			E												
14	K (13)																			E												
15	K (14)																			E												
16	W (7)																				D											
17	K (15)																				E											
18	K (16)																				E		E	E								
19	K (17)																				E		E	E		E						
20	K (18)																						D									E
21	W (8)																						E									
22	K (19)																						A									
23	W (9)																						E									
24	W (10)																							E								
25	W (12)																							E		A						
26	W (13)																							E		D						
27	W (14)																									E						
28	W (15)																									E						
29	W (16)																									D						D
30	K (20)																									A,B						
31	K (21)																									B						
32	K (22)																									A						
33	W (17)																													E	E	
34	K (23)																													E	E	
35	K (24)																													E		
36	W (18)																													E		
37	W (19)																													E		
38	K (25)																													A,B		E
39	W (20)																													E	D	
40	W (21)																													D		
41	W (22)																													E	E	E
42	W (23)																													E		
43	W (24)																													E		
44	W (25)																													E		
45	K (26)																															E
46	K (27)																															D
47(♀)	K (2)															D																
48(♀)	K (4)																	E														
49(♀)	K (5)																	E														
50(♀)	K (6)																	E														
51(♀)	W (2)																		E													
52(♀)	W (11)																							E		E						

Fig. 7. The marking and recapturing in 2005.

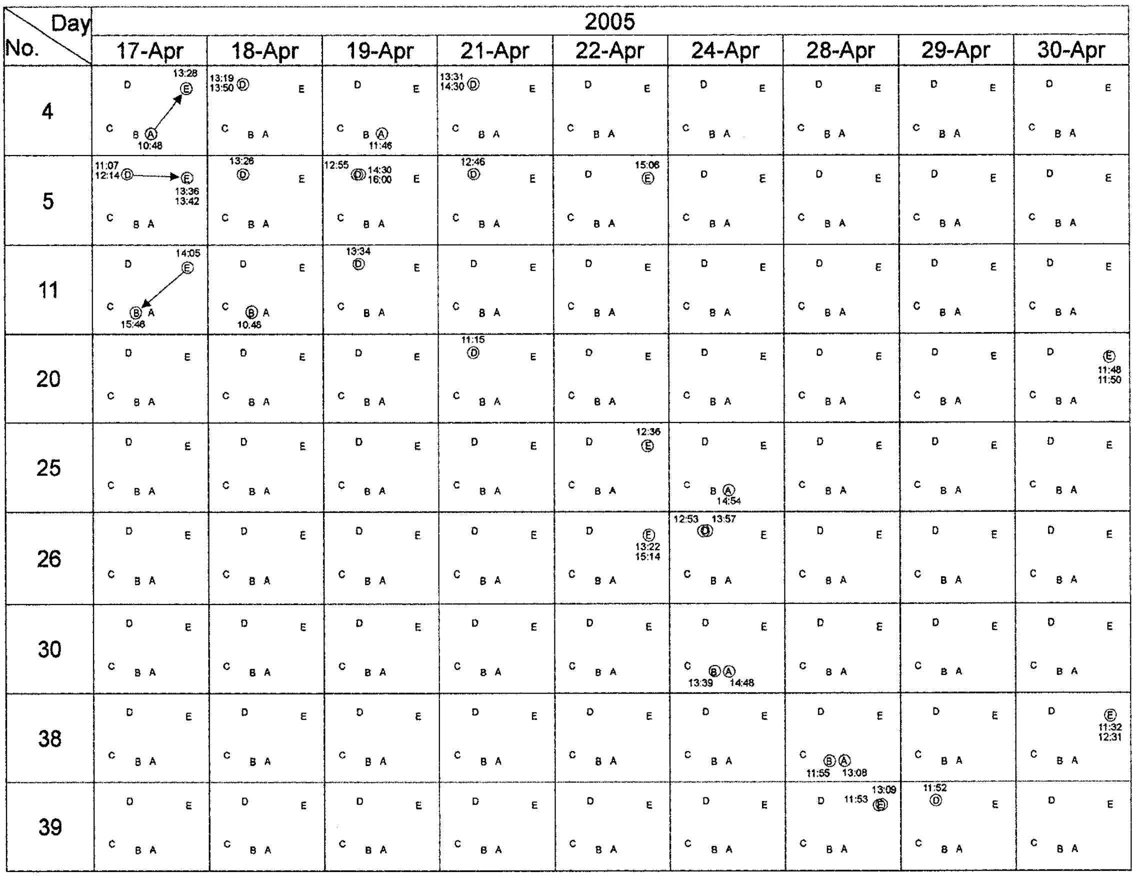

Fig. 8. The detailed peak-to-peak translocations in 2005, as far as was detected by our survey.

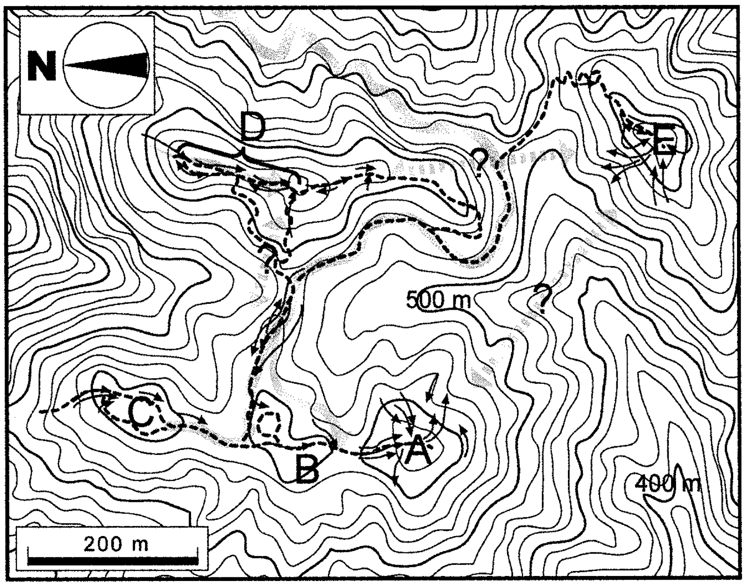

Fig. 9. The postulated flight route of *Luehdorfia japonica* in the summit area. Dotted lines indicate the paths for human beings.

Table 1. Activity of translocation in each individual calculated from Fig. 4, 6 and 8 (preliminary estimation).

Individual	total count of translocation (at least)	translocation in the same day (at least)	Times needed for recapturing on the same day (min)
(2003)			
No. 1	1	0	–
No. 11	2	1	25
No. 12	8	6	(45, 55), (40, 93), 58, 86
No. 13	2	1	28
No. 15	1	1	55
No. 18	1	1	58
No. 19	1	0	–
No. 21	1	1	4*
No. 26	3	1	126
No. 28	1	0	–
No. 30	1	1	20*
No. 41	1	0	–
No. 42	2	2	(71, 25)
	25	15	25–126 min.
(2004)			
No. 8	1	0	–
No. 9	1	1	137
No. 11	1	0	–
No. 12	5	5	(61*, 1*), 79, (158, 55)
No. 15	3	2	(2*, 62)
	11	8	55–158 min.
(2005)			
No. 4	4	1	160
No. 5	3	1	82
No. 11	2	1	101
No. 20	1	0	–
No. 25	1	0	–
No. 26	1	0	–
No. 30	1	1	69*
No. 38	2	1	73*
No. 39	1	0	–
	16	5	82–160 min.
Total	**52**	**28**	**25–160 min.**

Parenthesis means two times of translocation in the same day.
Star (*) means the translocation from A→B or B→A. As this is short distance, the times needed for this translocation are omitted from the discussion in the text.

We could not find a case of translocation at an earlier phase of their emergence; that is, the translocated individuals were always more or less stained. It seems to take at least four to five days after emergence to start the activities. The heavily stained individuals manifesting attenuated flight activities were repeatedly recaptured at the same peak and displayed no more translocations, suggesting the flights seemed to cease there. However, we observed that even such individuals can copulate when they encounter a virgin female. These facts indicate that the translocations are manifested mainly at the prime of life in males. Figs 5, 7 may suggest a tendency that many individuals would accumulate finally at Peak E.

Discussion

The most important thing is that actively-flying males do not generally drop out from the summit area. What is the mechanism? As our monitoring survey cannot cover all the peaks at all times, we cannot now describe the flights exactly. Accumulations of more field observations on targeted subjects, coupled with experimental analyses toward the elementary processes of flight orientation (Miller and Strickler, 1984), are required. Here, we briefly point out some problems.

1. What do the butterflies accomplish by peak-to-peak translocations?

The flight routes seem to be determined to some extent, because the directions of flight away from the peaks and of arrival at them are generally consistent (Watanabe and Hirano, 2006), and eye-witness points and the flight directions observed between the peaks for these 20 years have been quite restricted (Fig. 9). When we join the points, postulated flight routes can be elucidated, as shown in Fig. 9, and we emphasize that in our many hundred passages along the paths, we never saw the butterflies in areas other than those of the red arrows in Fig. 9. After straight and continuous flights, by which the butterflies passed over a narrow valley and/or a canopy of forest, they seemed to spend a considerable time staying at preferential points before arriving at the peaks. The flight routes seemed not to be necessarily circular, but, as a result of peak-to-peak orientation, the routes became continuous and closed circle.

We could not strictly determine why many individuals tended to cease their flight activities at Peak E and accumulated there in 2004, 2005 (Figs 5, 7). However, it is interesting to note that the flight activities may be somehow integrated, and that Peak E may have an unknown condition affecting behavior. One attractive explanation is that the peak-to-peak translocations might be explained as an expansion of the flight area from the "round patrolling with resting points" (Watanabe and Hirano, 2006). Furthermore, as a base point for avoiding divergence, the butterflies use a specified location (peak) and converge there finally. Further observations are required.

2. Adaptive implications

Population divergence by flight is the most dangerous factor threatening meta-population maintenance. If the mechanism failed to work, virgin females would hardly meet males, and mated females could rarely get to their food plant to oviposit. The species, therefore, should provide specific mechanisms in their flight activities to prevent population divergence. The persistent peak-to-peak restriction of males can be understood in this context. Thus, on male flight behaviors in *Luehdorfia japonica* at a summit area, we can list up at least three categories: one is round-patrolling with specific resting points, the second is perching occupation with repeated circular flights (Watanabe and Hirano, 2006), and the third is occasional peak-to-peak translocation.

After all, we have to remember that the restriction of male behaviors is a statistical process, depending on the interaction between environmental changes and the variable intrinsic physiologies of individuals (Miller and Strickler, 1984). Accordingly, it is invariably noteworthy that certain males occasionally fly away from a summit area and migrate out from a meta-population, depending on the environmental conditions and individual physiologies. These males can thus contribute to the diversification of gene pool of the species (Watanabe *et al.*, 2000; Hirowatari and Watanabe, 2000). Female activity is another important problem to be investigated.

Acknowledgments

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摘　　要

ギフチョウの山頂間移動 (平野和比古・渡辺一雄・亀山剛)

2002年度の調査 (Watanabe and Hirano, 2006) によって, 谷で互いに隔てられたピーク間 (直線距離で340 m) の1雄個体の往復移動が確認されたので, 2003年, 2004年, 2005年の3年間, 著者らは計123個体 (雄115個体, 雌8個体) をマーキングし, 直線距離で互いに約125–460 m離れた4つのピークの間でマーク個体の移動状況を追跡した. その結果, 雄において, 累計52回のピーク間移動が計27個体で確認された. さらに, 52回のうち28回は同日内の移動であった. すなわち, ギフチョウの雄はピークを含む尾根筋に執着した周回性, 回帰性の飛翔を示す場合があり, その頻度は相当に高いと考えられた. この山頂間移動は, 前報 (Watanabe and Hirano, 2006) で述べた巡回飛翔 (round patrolling) の拡張という観点から考察された. すなわち, ギフチョウの雄は, この山頂固執性により散逸を防止しつつ相当に広い範囲の巡回行動を可能とし, 同時にらせん飛翔に伴う追い出し行動によって spacing-out し合い, 複数の雄個体の同一地点への集積を防止している. これによって, 複数の雄個体がより広い山頂部を同時的にカバーしあい, ピークに登ってくる未交尾雌との遭遇機会を増大させていると考察された.

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